

*Sub 16*  
porosity in the range of about 70% to 98% within said polymeric support,  
at least one ion exchange resin filling said microstructure such that said composite  
membrane is air impermeable, said composite membrane having a thickness of at most 0.8 mils  
and an ionic conductance rate of at least 5.1  $\mu$ mhos/min.

*99*  
~~100~~ 101. The composite membrane of claim ~~100~~, wherein said polymeric support is a polyolefin.

*99*  
~~101~~ 102. The composite membrane of claim ~~100~~, wherein said polymeric support is a fluorinated  
polymer.

*99*  
~~102~~ 103. The composite membrane of claim ~~100~~, wherein said polymeric support is a chlorinated  
polymer.

*101*  
~~103~~ 104. The composite membrane of claim ~~102~~, wherein said fluorinated polymer is  
polytetrafluoroethylene.

*103*  
~~104~~ 105. The composite membrane of claim ~~104~~, wherein said polytetrafluoroethylene is expanded  
polytetrafluoroethylene.

*99*  
~~105~~ 106. The composite membrane of claim ~~100~~, wherein said polymeric support is a polyamide.

*99*  
~~106~~ 107. The composite membrane of claim ~~100~~, wherein said polymeric support is a  
polycarbonate.

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- ~~107~~ 108. The composite membrane of claim ~~102~~<sup>101</sup>, wherein said microstructure includes nodes interconnected with fibrils.
- ~~106~~ 109. The composite membrane of claim ~~104~~<sup>103</sup>, wherein said microstructure includes nodes interconnected with fibrils.
- ~~107~~ 110. The composite membrane of claim ~~100~~<sup>99</sup>, wherein the thickness of said composite membrane is in the range of between 0.06 and 0.8 mils.
- B10  
C11* 110. The composite membrane of claim ~~100~~<sup>99</sup>, wherein the thickness of said composite membrane is in the range of between about 0.5 and 0.8 mils.
- 111 112. The composite membrane of claim ~~100~~<sup>99</sup>, wherein the thickness of said composite membrane is at most 0.5 mils.
- 112 113. The composite membrane of claim ~~100~~<sup>99</sup>, wherein said at least one ion exchange resin comprises a mixture of ion exchange resins.
- 113 114. The composite membrane of claim ~~100~~<sup>99</sup>, wherein said at least one ion exchange resin comprises a perfluorinated sulfonic acid resin.
- 114 115. The composite membrane of claim ~~100~~<sup>99</sup>, wherein said at least one ion exchange resin comprises a perfluorinated carboxylic acid resin.

~~115 116.~~ The composite membrane of claim ~~100~~<sup>99</sup>, wherein said at least one ion exchange resin comprises a polyvinyl alcohol.

~~116 117.~~ The composite membrane of claim ~~100~~<sup>99</sup>, wherein said at least one ion exchange resin comprises a divinyl benzene resin.

~~117 118.~~ The composite membrane of claim ~~100~~<sup>99</sup>, wherein said at least one ion exchange resin comprises a styrene-based polymer.

~~118 119.~~ The composite membrane of claim ~~100~~<sup>99</sup>, wherein said at least one ion exchange resin further comprises metal salts with or without a polymer.

*B10  
C9*  
~~119 120.~~ The composite membrane of claim ~~113~~<sup>112</sup>, wherein said mixture of ion exchange resins includes at least two of a perfluorinated sulfonic acid resin, a perfluorinated carboxylic acid resin, a polyvinyl alcohol resin, a divinyl benzene resin or a styrene-based polymer.

~~120 121.~~ The composite membrane of claim ~~100~~<sup>99</sup>, wherein said at least one ion exchange resin is a perfluorosulfonic acid/tetrafluoroethylene copolymer resin.

~~121 122.~~ The composite membrane of claim ~~100~~<sup>99</sup>, further comprising a reinforcement backing bonded to a side thereof.

*Rule 123* 122. An integral substantially air occlusive integral composite membrane having a polymeric support with a microstructure of pores, said microstructure filled with an ion exchange resin, said composite membrane has an ionic conductance rate of at least 5.1  $\mu\text{mhos}/\text{min}$ , said composite membrane prepared by,

- (a) providing a polymeric support having a microstructure of micropores;
- (b) sequentially applying an ion exchange resin solution to each major surface of said polymeric support; and
- (c) repeating step (b) until said micropores are sufficiently filled with ion exchange resin to form an air occlusive integral composite membrane.

*123* 123. The composite membrane of claim *123*, wherein said step (b) further includes,  
(b1) drying said support after each application of ion exchange resin solution to remove solvent from said solution.

*124* 124. The composite membrane of claim *123*, wherein said step (b) includes at least three successive applications of said ion exchange resin solution.

*125* 125. The composite membrane of claim *123*, wherein said step (b) includes at least four successive applications of said ion exchange resin solution.

*126* 126. The composite membrane of claim *123*, wherein said step (b) includes at least three

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- successive applications of said ion exchange resin solution, each followed by a drying step.
- 127 128. The composite membrane of claim 123, wherein said step (b) includes at least four successive applications of said ion exchange resin solution, each followed by a drying step.
- 128 129. The composite membrane of claim 123, wherein said support comprises a polyolefin.
- 129 130. The composite membrane of claim 123, wherein said support comprises a fluorinated polymer.
- 130 131. The composite membrane of claim 123, wherein said support comprises a chlorinated polymer.
- 131 132. The composite membrane of claim 123, wherein said fluorinated polymer is polytetrafluoroethylene.
- 132 133. The composite membrane of claim 123, wherein said polytetrafluoroethylene is expanded polytetrafluoroethylene.
- 133 134. The composite membrane of claim 123, wherein said support comprises a polyamide.
- 134 135. The composite membrane of claim 123, wherein said support comprises a polycarbonate.
- 135 136. The composite membrane of claim 123, where said microstructure includes nodes

*Rule 12e*  
interconnected with fibrils.

*136 137* The composite membrane of claim *123*, having a thickness in the range between 0.06 and 0.8 mils.

*137 138* The composite membrane of claim *137*, having a thickness in the range of between about 0.5 and at most 0.8 mils.

*138 139* The composite membrane of claim *137*, having a thickness of at most about 0.5 mils.

*139 140* The composite membrane of claim *123*, wherein said ion exchange resin is a mixture of resins.

*140 141* The composite membrane of claim *123*, wherein said ion exchange resin is a perfluorinated sulfonic acid resin.

*141 142* The composite membrane of claim *127*, wherein said drying is conducted at about room temperature.

*142 143* The composite membrane of claim *123*, wherein said ion exchange resin solution is applied in the presence of a surfactant.

*143 144* The composite membrane of claim *124*, wherein said ion exchange resin solution is

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applied in the presence of a surfactant.

- 144* 145. A method of preparing a substantially air occlusive integral composite comprising:
- providing a polymeric support having a microstructure of micropores;
  - sequentially applying an ion exchange resin solution to each major surface of said polymeric support; and
  - repeating step (b) until said micropores are sufficiently filled with ion exchange resin to form an air occlusive integral composite membrane which has an ionic conductance rate of at least 5.1  $\mu$ mhos/min.
- 144* 146. The method of claim *145*, wherein said step (b) includes at least three successive applications of said ion exchange resin solution.
- 144* 147. The method of claim *145*, wherein said step (b) includes at least four successive applications of said ion exchange resin solution.
- 144* 148. The method of claim *145*, wherein said step (b) includes at least two successive applications of said ion exchange resin solution, each followed by a drying step.
- 144* 149. The method of claim *145*, wherein said step (b) includes at least three successive applications of said ion exchange resin solution, each followed by a drying step.

<sup>144</sup>  
149 150. The method of claim <sup>145</sup>, wherein said providing step (a) comprises providing as said polymeric support a polyolefin support.

<sup>144</sup>  
150 151. The method of claim <sup>145</sup>, wherein said providing step (a) comprises providing as said polymeric support a fluorinated polymer support.

<sup>144</sup>  
151 152. The method of claim <sup>145</sup>, wherein said providing step (a) comprises providing as said polymeric support a chlorinated polymer support.

<sup>150</sup>  
<sup>B</sup> 152 153. The method of claim <sup>151</sup>, wherein said fluorinated polymer is polytetrafluoroethylene.

<sup>152</sup>  
<sup>C</sup> 153 154. The method of claim <sup>153</sup>, wherein said polytetrafluoroethylene is expanded polytetrafluoroethylene.

<sup>144</sup>  
154 155. The method of claim <sup>145</sup>, wherein said providing step (a) comprises providing as said polymeric support a polyamide.

<sup>144</sup>  
155 156. The method of claim <sup>145</sup>, wherein said providing step (a) comprises providing as said polymeric support a polycarbonate support.

<sup>144</sup>  
156 157. The method of claim <sup>145</sup>, where said microstructure includes nodes interconnected with fibrils.

157 158. The method of claim 145, wherein said composite membrane has a thickness within the range of 0.06 to 0.8 mils.

158 159. The method of claim 145, wherein said composite membrane has a thickness within the range of 0.5 to 0.8 mils.

159 160. The method of claim 145, wherein said composite membrane has a thickness of at most 0.5 mils.

160 161. The method of claim 145, wherein said ion exchange resin is a mixture of resins.

161 162. The method of claim 145, wherein said ion exchange resin is a perfluorinated sulfonic acid resin.

162 163. The method of claim 146, wherein said at least three successive applications of said ion exchange solution include alternate applications of said resin solution to a first side of said support and then to a second side of said support.

163 164. A fuel cell including an ultra-thin, air impermeable integral composite membrane; said composite membrane comprising:  
a polymeric support having a microstructure of micropores, said microstructure defining a porosity in the range of about 10% to 95% within said polymeric support,

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at least one ion exchange resin filling said microstructure such that said composite membrane is air impermeable, said composite membrane having a thickness of at most 0.8 mils.

- 164 165.* The fuel cell of claim *164*, wherein said polymeric support is a fluorinated polymer.
- 165 166.* The fuel cell of claim *165*, wherein said fluorinated polymer is polytetrafluoroethylene.
- 166 167.* The fuel cell of claim *164*, wherein said microstructure includes from nodes interconnected with fibrils.
- 167 168.* The fuel cell of claim *164*, wherein said composite membrane has a thickness in the range of between 0.06 and at most 0.8 mils.
- 168 169.* The fuel cell of claim *168*, wherein said composite membrane has a thickness of at most 0.5 mils.
- 169 170.* The fuel cell of claim *168*, wherein said at least one ion exchange resin comprises a mixture of ion exchange resins.
- 170 171.* The fuel cell of claim *164*, wherein said at least one ion exchange resin comprises a perfluorinated sulfonic acid resin.

*Surfactant* 171 172. The method according to claim 145, wherein step (b) is performed in the presence of a surfactant.

*Surfactant* 172 173. The composite membrane of claim 110, wherein the thickness of said composite membrane is at most 0.4 mils.

*Surfactant* 173 174. The composite membrane of claim 110, wherein the thickness of said composite membrane is at most 0.3 mils.

*B3 C10* 174 175. The composite membrane of claim 110, wherein the thickness of said composite membrane is at most 0.2 mils.

*Cov 10* 175 176. The composite membrane of claim 110, wherein the thickness of said composite membrane is at most 0.1 mils.

176 177. The composite membrane of claim 137, wherein the thickness of said composite membrane is at most 0.4 mils.

177 178. The composite membrane of claim 137, wherein the thickness of said composite membrane is at most 0.3 mils.

178 179. The composite membrane of claim 137, wherein the thickness of said composite membrane is at most 0.2 mils.

- John J. [Signature]* 180. The composite membrane of claim ~~137~~<sup>136</sup>, wherein the thickness of said composite membrane is at most 0.1 mils.
- John J. [Signature]* 181. The composite membrane of claim ~~145~~<sup>144</sup>, wherein said step (b) further includes,  
(b1) drying said support after each application of ion exchange resin solution to remove solvent from said solution.
- B. [Signature]* 182. The composite membrane of claim ~~158~~<sup>157</sup>, wherein the thickness of said composite membrane is at most 0.4 mils.
- B. [Signature]* 183. The composite membrane of claim ~~158~~<sup>157</sup>, wherein the thickness of said composite membrane is at most 0.3 mils.
- B. [Signature]* 184. The composite membrane of claim ~~158~~<sup>157</sup>, wherein the thickness of said composite membrane is at most 0.2 mils.
- B. [Signature]* 185. The composite membrane of claim ~~158~~<sup>157</sup>, wherein the thickness of said composite membrane is at most 0.1 mils.
- B. [Signature]* 186. The composite membrane of claim ~~168~~<sup>167</sup>, wherein the thickness of said composite membrane is at most 0.4 mils.